ENVIRONMENTAL SCIENCE AND TECHNOLOGY

WSRC-RP-2001-00334, Rev. 1

UNCERTAINTY IN TRANSPORT FACTORS USED TO CALCULATE DOSE FROM I-131 RELEASES AT SRS FOR THE PERIOD OF 1955-1961

Ali A. Simpkins

Technical Reviewer

August 2001

Westinghouse Savannah River Company
Savannah River Site
Aiken, SC 29808

PREPARED FOR THE U.S. DEPARTMENT OF ENERGY UNDER CONTRACT NO. AC09-96SR18600

This document was prepared in conjunction with work accomplished under Contract No. DE-AC09-96SR18500 with the U.S. Department of Energy

DISCLAIMER

Key Words Iodine
Uncertainty
Atmospheric Releases

Retention: Lifetime

UNCERTAINTY IN TRANSPORT FACTORS USED TO CALCULATE DOSE FROM I-131 RELEASES AT SRS FOR THE PERIOD OF 1955-1961

A. A. Simpkins

Issued: August 2001

SRTC

SAVANNAH RIVER TECHNOLOGY CENTER
AIKEN, SC 29808
Westinghouse Savannah River Company
Savannah River Site
Aiken, SC 29808

PREPARED FOR THE U.S. DEPARTMENT OF ENERGY UNDER CONTRACT NO. DE-AC09-96SR18500

ABSTRACT

During the 1950's, atmospheric release of I-131 was one of the largest contributors to offsite dose at the Savannah River Site (SRS). Many parameters with wide ranges of uncertainty are used to estimate the dose resulting from a given air concentration or deposition. Transport factors are defined as that factor which is multiplied by the air concentration (or deposition) and the appropriate dose conversion factor to estimate dose. Uncertainties are estimated for the period of 1955-1961 for all parameters contributing to the transport factor for each pathway. These uncertainties will then be used in conjunction with research being conducted by Dr. Hamby at Oregon State University to propagate a probabilistic dose. This work was funded by the Centers for Disease Control and Prevention.

TABLE OF CONTENTS

1. INTRODUCTION **1**

2. BACKGROUND **1**

3. DETERMINATION OF UNCERTAINTY **4**

3.1. INHALATION PATHWAY 8
3.2. VEGETABLE AND LEAFY VEGETABLE CONSUMPTION PATHWAY 9
3.3. MILK AND BEEF CONSUMPTION PATHWAYS 12
3.4. GROUND SHINE PATHWAY 15
3.5. UNCERTAINTY IN TRANSPORT FACTORS 16

4. CONCLUSIONS **18**

5. REFERENCES **19**

LIST OF TABLES

TABLE 1. DOSE CONTRIBUTION FOR UNIT RELEASE OF IODINE-131 FROM SRS CENTER........................ 5

TABLE 2. PARAMETER SENSITIVITY IN I-131 DOSE CALCULATION... 6

TABLE 3. PARAMETER UNCERTAINTY... 7

LIST OF FIGURES

FIGURE 1. TRANSPORT FACTOR FOR INHALATION 16

FIGURE 2. TRANSPORT FACTOR FOR INGESTION OF VEGETABLES 17

FIGURE 3. TRANSPORT FACTOR FOR INGESTION OF MILK 17

FIGURE 4. TRANSPORT FACTOR FOR INGESTION OF BEEF.. 17

FIGURE 5. TRANSPORT FACTOR FOR SHINE.. 18

UNCERTAINTY IN TRANSPORT FACTORS USED TO CALCULATE DOSE FROM I-131 RELEASES AT SRS FOR THE PERIOD OF 1955-1961[1]

By A. A. Simpkins

Westinghouse Savannah River Company
Savannah River Site
Aiken, SC 29808

1. INTRODUCTION

During the 1950's, atmospheric release of I-131 was one of the largest contributors to offsite dose at the Savannah River Site (SRS). Offsite dose is estimated for the following pathways: 1) inhalation; 2) ingestion of milk, meat, and vegetables, and 3) plume and ground shine. Many parameters with wide ranges of uncertainty are used to estimate the dose for each of these pathways.

Pathway-specific transport factors are defined as that factor which is multiplied by either air concentration or ground deposition and the appropriate dose conversion factor to estimate dose. Uncertainties are estimated for the period of 1955-1961 for transport factors for each pathway. The years 1955-1961 were chosen because more than 95% of the I-131 released at SRS was during this time period.

2. BACKGROUND

Routine atmospheric release dose models used at SRS strictly follow U. S. Nuclear Regulatory Commission (NRC) Guides 1.109 and 1.111 (USNRC 1977a, 1977b). The model used at SRS to determine the dose for the maximally exposed offsite individual (MEI) is MAXDOSE-SR (Simpkins, 1999). Doses for the MEI are determined by summing the dose contribution for various pathways as represented by the following equation:

$$D = D_{inh} + D_{veg} + D_{beef} + D_{milk} + D_{plume} + D_{ground} \quad (1)$$

where

D_{inh} dose contribution from inhalation

D_{veg} dose contribution from ingestion of vegetables (leafy and other)

[1] This work was performed under a grant with the Centers for Disease Control and Prevention (no. R32/CCR018377-01).

D_{beef} dose contribution from ingestion of beef

D_{milk} dose contribution from ingestion of milk (cow or goat)

D_{plume} dose contribution from plume shine

D_{ground} dose contribution from ground shine

Each of the doses discussed above are represented by a generic equation:

$$D = DCF \bullet TF_p \bullet C \bullet CF \tag{2}$$

where

DCF dose conversion factor

TF_p transport factor for pathway p

C concentration (air or ground, as appropriate)

CF conversion factor (if necessary – seconds to years – millirem-rem, etc.)

Using Simpkins (1999), the transport factors can be calculated from the equations used to estimate dose. For the inhalation dose pathway the transport factor is as follows:

$$TF_{inh} = \{(1 - F_I) + DEP \bullet F_I\} \bullet BR \bullet e^{-\lambda t} \tag{3}$$

where

TF_{inh} transport factor for inhalation dose (m^3/yr)

F_I fraction of iodine that is elemental (unitless)

DEP depletion factor (unitless)

BR breathing rate (m^3/yr)

λ radioactive decay constant (1/yr)

t time period from release to receptor (yr)

Dose contribution from the ingestion of vegetables is calculated separately for leafy and other vegetables. The transport factor equation used for leafy and other vegetables is the same, but some of the parameters are assigned different values. The transport factor for vegetables is as follows:

$$TF_{veg} = \left[U_v f_v f_I \bullet e^{-\lambda_i t} \bullet \left[\frac{r_i (1 - e^{-\lambda_i^w t_e})}{Y_V \lambda_i^w} + \frac{B_i (1 - e^{-\lambda t_b})}{P \bullet \lambda} \right] \bullet e^{-\lambda t_h} \right] \quad (4)$$

where

TF_{veg} transport factor for vegetable type leafy or other (m^2/yr)

U_v consumption rate of vegetables (kg/yr)

f_v fraction of vegetables that are home grown (unitless)

f_I fraction of iodine assumed to be elemental (unitless)

r_i fraction of the nuclide deposited that remains on the surface of the plant (unitless)

λ_i^w decay constant that represents both weathering and radioactive losses (1/yr)

t_e crop exposure time (yr)

Y_v crop productivity (kg/m^2)

B_i element-specific soil/plant uptake ratio (unitless)

t_b time period over which the buildup of radionuclides occurs (yr)

P surface soil density (kg/m^3)

t_h hold-up time after harvest (yr)

For ingestion of beef and milk, the same equation is used to calculate the transport factors however different parameters are used. The terms in parentheses represent the two separate ingestion pathways of grazing and the consumption of stored feed.

$$TF_{cow} = \left\{ f_p f_s \left[\frac{r_i (1 - e^{-\lambda_i^w t_e})}{Y_g \lambda_i^w} + \frac{B_i (1 - e^{-\lambda t_b})}{P \bullet \lambda} \right] + \left[f_p (1 - f_s) + (1 - f_p) \right] \left[\frac{r_i (1 - e^{-\lambda_i^w t_e})}{Y_{sf} \lambda_i^w} + \frac{B_i (1 - e^{-\lambda t_b})}{P \bullet \lambda} \right] \right\} \bullet$$

$$e^{-\lambda t_h} \bullet ft \bullet Q \bullet e^{-\lambda t_t} \bullet U_{cow} \quad (5)$$

where

TF_{cow} transport factors for ingestion of beef or milk (m^2/yr)

f_p fraction of time cattle spend on pasture (unitless)

f_s fraction of time cattle graze while on pasture (unitless)

ft feed transfer coefficients for beef cow and milk cows (d/L or d/kg)

Q cattle feed rates for beef and milk cows (kg/yr)

t_t transport times for beef and milk (yr)

U_{cow} consumption rates of beef or milk (kg/yr)

All other terms have been previously defined.

Immersion in a radioactive plume of I–131 contributes an inconsequential dose to the receptor since plume shine dose is typically only estimated for noble gases; therefore, this pathway is not addressed.

For ground shine dose the transport factor is as follows:

$$TF_{ground} = SF \bullet \frac{1 - e^{-\lambda t_b}}{\lambda} \bullet e^{-\lambda t} \tag{6}$$

where

TF_{ground} transport factor for ground shine (m^2/yr)

SF shielding factor, (unitless)

Other terms have been previously defined.

For each of the transport factors previously discussed, a probabilistic distribution is desired which can be used in equation 2 along with other distributions to estimate on overall probabilistic dose. To estimate this probabilistic distribution, each parameter is examined and an uncertainty range is assigned using a mean value and an appropriate distribution.

3. DETERMINATION OF UNCERTAINTY

Looking at equations two through six shown above, there are many parameters for which to assign uncertainty. To cost-effectively perform the research, efforts need to be concentrated on parameters that have a greater effect on resulting dose. To determine which pathways are of the greatest importance for an atmospheric release of I-131, a simple dose calculation was performed using MAXDOSE-SR (Simpkins 1999).

For a unit release of elemental I-131 from the center of SRS, the dose breakdown by pathway is shown in Table 1. For an atmospheric release of I-131 a majority of the dose to humans is contributed by the ingestion of vegetables and milk. Therefore, when estimating the uncertainty in transport factors, parameters used to estimate the dose from these pathways will be examined more carefully.

Table 1. Dose Contribution for Unit Release of Iodine-131 from SRS Center

Pathway	Dose (mrem)	% of total
Plume	0	0%
Ground	1.2E-04	1%
Vegetation	8.2E-03	74%
Beef	3.6E-04	3%
Milk	2.2E-03	20%
Inhalation	1.8E-04	2%
Total	1.1E-02	

To further define specific research areas, a Microsoft Excel spreadsheet entitled MAXINE (Hamby 1994) was used to determine which parameters had the greatest effect on dose. The methodology within MAXINE is based on MAXDOSE-SR (Simpkins 1999). Both codes determine dose to the maximally exposed offsite individual for routine releases of atmospheric radioactive materials to the environment. MAXINE, however, does not include an atmospheric dispersion model, but rather uses relative air concentrations and deposition values determined by MAXDOSE-SR. These concentrations are then used to estimate the dose from all pathways.

To determine the relative importance of parameters on resulting dose, each parameter was assigned a uniform distribution centered on currently used average values with a range of ±50%. For certain terms where this range was not feasible (i.e. value of 1 with valid range of 0 -1), adjustments were made. Also, for the half-life parameter, which has a high degree of certainty, a narrow range was used. The relative air concentrations, deposition values, source term and dose conversion factor were assumed to be constant. Crystal Ball© was used to perform a sensitivity analysis of the resulting dose. Crystal Ball© is a forecasting and risk analysis program that runs with Microsoft Excel ©.

The results of this analysis are shown in Table 2. Results are shown as a percent contribution to overall uncertainty and parameters whose contribution is equal to or less than 0.1% are not shown. As expected, those parameters associated with vegetable consumption contribute most to overall uncertainty. However, this analysis further refines which parameters need careful consideration of their respective uncertainty.

Table 3 shows a list of all variables used to determine the transport factors along with their assigned values and uncertainty ranges. The determination of uncertainty for each variable is then discussed. For those parameters that are the same for different pathways (i.e. soil density), they are only listed once. Parameters are discussed in the order in which they appeared in Section 2.

Table 2. Parameter Sensitivity in I-131 Dose Calculation
(in order of decreasing sensitivity)

Parameter	**Relative Sensitivity (%)**
Produce Productivity	23.4
Leafy Vegetable Consumption	18.1
Retained Fraction (Iodines)	17.0
Elemental Iodine Fraction	16.8
Fraction of Leafy-Veg from Garden	6.6
Weathering Rate Constant	4.0
Produce Holdup Time	3.6
Pasture Grass Productivity	2.4
Milk Cattle Feed Consumption	1.4
Milk Transfer Factor	1.4
Milk Consumption	1.3
Fraction of year on Pasture (milk)	1.3
Pasture Grass Holdup Time	0.8
Vegetable Consumption	0.4
Breathing Rate	0.4
Fraction of Intake from Pasture (milk)	0.2
Leafy Vegetable Holdup Time	0.2

Table 3. Parameter Uncertainty

Symbol	Parameter (units)	Dist Type[1]	Mean[2]	Standard Deviation or Range[3]
F_I	Fraction of iodine that is elemental (unitless)	U		0-0.6
DEP	Depletion factor (unitless)	N	0.7	0.07
BR	Breathing rate (m^3/y)	N	8500	1700
λ	Radioactive decay constant (1/y)	T	8.0207	±0.1%
t	Time period from release to receptor (y)	C	0	
U_v	Consumption rate of vegetables (kg/y)	LN	150	2.0
U_{lv}	Consumption rate of leafy vegetables (kg/y)	LN	19	2.0
f_v	Fraction of vegetables that are home grown (unitless)	T	0.5	0.25-0.75
f_{lv}	Fraction of leafy vegetables that are home grown (unitless)	T	0.5	0.25-1.0
r_i	Fraction of nuclide remaining on plant surface (unitless)	U		0.09-0.9
λ^w	Decay and weathering losses (1/y) (sum with λ)	LN	18.07	1.4
t_e	Crop exposure time (yr)	N	70	.7
Y_v	Vegetable productivity (kg/m^2)	LN	0.6	1.4
Y_{lv}	Leafy vegetable productivity (kg/m^2)	LN	0.6	1.4
B_i	Soil/plant uptake ratio (unitless)	U		0.02-0.2
t_b	Buildup time of radionuclides (y)	U		1-7
P	Surface soil density (kg/m^3)	N	240	17
t_{hv}	Hold-up time after harvest-other vegetables (y)	N	6	0.6
t_{hlv}	Hold-up time after harvest-leafy (y)	N	1	0.1
f_{pm}	Fraction of time milk cattle spend on pasture (unitless)	U		0.75-1.0
f_{pb}	Fraction of time beef cattle spend on pasture (unitless)	U		0.75-1.0
f_{sm}	Fraction of time milk cattle graze while on pasture (unitless)	U		0.5-0.75
f_{sb}	Fraction of time beef cattle graze while on pasture (unitless)	U		0.5-0.75
ft_m	Feed transfer coefficients for milk cows (d/L)	LN	0.012	2.0
ft_b	Feed transfer coefficients for beef cows (d/kg)	LN	0.0029	2.2
Q_{milk}	Feed rate for milk cow (kg/d)	N	52	11
Q_{beef}	Feed rate for beef cow (kg/d)	N	36	7.8
t_{e-p}	Crop exposure time for pasture grass (y)	N	70	0.7
t_{e-sf}	Crop exposure time for stored feed(y)	N	70	0.7
t_{h-p}	Hold-up time after harvest-pasture grass (y)	Cust		0.75(0),0.25 (0.019)
t_{h-sf}	Hold-up time after harvest- stored feed (d)	N	90	0.9
t_{tm}	Transport time for milk (d)	LN	3	1.5
t_{tb}	Transport time for beef (d)	LN	6	1.4
Y_p	Pasture grass productivity (kg/m^2)	LN	0.7	1.8
Y_{sf}	Productivity of stored feed (kg/m^2)	LN	0.4	1.4
U_{milk}	Consumption rate of milk (kg/y)	LN	140	2.6
U_{beef}	Consumption rate of beef (kg/y)	LN	90	2.6
SF	Shielding factor (unitless)	U		0-1.0

[1] Distributions: LN – lognormal, N – Normal, T, Triangular, U – Uniform, C-constant, and Cust - custom

[2] Arithmetic Mean for normal and lognormal distributions and mode for triangular distributions.

[3] Standard Deviation for Normal distribution, geometric standard deviation for Lognormal distributions and range shown for all others.

3.1. Inhalation Pathway

3.1.1. Fraction of Iodine that is Elemental

Before iodine is released to the atmosphere it passes through an emission control system consisting of a demister filter bank, a high efficiency particulate air (HEPA) filter and a carbon filter bed. These processes remove greater than 99.9 % of the iodine from the process ventilation air (Kantelo, et al. 1990). Of the iodine remaining, very little has been done at SRS to quantify the amount that is elemental.

According to USNRC. Regulatory Guide 1.109 'half the radioiodine emissions may be considered nonelemental.' Studies at Hanford (Perkins 1963) indicated that less than one-third of the radioiodine released was elemental. However, at SRS, according to Kantelo et al. (1990) 'Elemental iodine…appears to be a minor constituent of the chemical forms of iodine in stack air.' Using this information, the range seems to be roughly between 10% to 50% elemental. To ensure all possible ranges are covered, this parameter is assigned a uniform distribution with a range of 0 to 0.6.

3.1.2. Depletion Factor

The depletion factor is determined by MAXDOSE using equations which approximate the depletion curves in USNRC Regulatory Guide 1.111 (USNRC 1977b). For center of site elevated releases, the depletion factor at the site boundary is approximately 0.7. A normal distribution is somewhat arbitrarily assigned with a standard deviation of 0.07. Within the MAXINE spreadsheet, this term does not appear directly, but rather is a multiplier used to determine the decayed and depleted relative air concentration. The depletion term is therefore accounted for by setting the decayed and depleted relative air concentration to the mean value of 0.7 instead of a constant value of one.

3.1.3. Breathing Rate

The distribution of annual breathing rate is best described by a normal distribution with a mean of 8,500 m^3/yr and a standard deviation of 1,700 m^3/yr (Hamby 1993). This differs slightly from the US NRC default of 8,000 m^3/yr (US NRC 1977a).

3.1.4. Decay Constant

The decay constant is assumed to be a highly precise number with little variation and therefore a triangular distribution was assigned with a mode of 8.0207 and a range of ±0.1% (Hamby and Benke 1999).

3.1.5. Time Period From Release to Receptor

The average distance to the site boundary for a center of site release is roughly 10 miles. At the average wind speed of about 4 m/s, the plume travel time to the site boundary is about 1 hour. Given that the half-life of I-131 is 8 days, a one-hour travel time would reduce the activity by less than 1%. For conservatism, the travel time is assumed to be a constant value of zero.

3.2. **Vegetable and Leafy Vegetable Consumption Pathway**

3.2.1. Consumption Rate of Vegetables

According to USNRC Regulatory Guide 1.109 (USNRC 1977a) the recommended usage value for the MEI for the consumption of fruits, vegetables (other than leafy), and grains is 520 kg/yr for adults. This value is only to be used in lieu of site-specific data. The land and water use study done at SRS in 1990 (Hamby, 1991) yielded a maximum value of 276 kg/yr and an average value of 163 kg/yr. These values were estimated from an USDA survey for 1977-1978 for southern households (USDA 1983). According to a 1965 USDA survey, the average consumption of fruits, vegetables and grains was 176 kg/yr for adults (USDA 1965).

The USDA performed household surveys in 1955 by region for foods used (USDA 1955). The drawback with this survey is that it is for entire household of which the number of individuals can vary. Also, foodstuff used does not take into account waste. For households of only one person in all urbanization's (rural and urban) in the south, the total vegetable, fruit and grain intake averaged 446 kg/yr which includes leafy vegetables and waste that is discarded. Considering that this value included waste that is discarded with no known percentages, these numbers are of little value.

During the late fifties, diets in the south were particularly poor, meaning that a significant portion did not meet the later-defined criteria for recommended daily allowance (RDA) of vitamins and minerals (Tippett et. al 1999). Diets were also high in fat with meat consumption and whole milk consumption being higher than when compared with today. This information implies that vegetable consumption was lower in the late fifties.

Considering that vegetable consumption was lower during the time period of the late fifties, a mean value of 150 kg/yr is somewhat arbitrarily assigned to this parameter which is slightly lower than the averages for the two later surveys. As Hamby (1993) recommends a lognormal distribution is assumed. A geometric standard deviation of 2.0 is estimated from plotting percentile consumption values within Pao et al. (1982).

3.2.2. Consumption Rate of Leafy Vegetables

Leafy vegetables include cabbage, lettuce, and dark-green leafy vegetables. The consumption rate of leafy vegetables is determined using similar logic to that of non-leafy vegetables. USNRC (1977a) assumes a maximum value of 64 kg/yr for adults. The land and water use study (Hamby, 1991) done at SRS in 1990 yielded a value maximum value of 43 kg/yr and an average value of 21 kg/yr. These values were estimated from an USDA survey for 1977-1978 for southern households (USDA 1983).

Considering the lower vegetable consumption during the fifties as discussed above, a mean value of 19 kg/yr is somewhat arbitrarily assigned to a lognormal distribution with a geometric standard deviation of 2.0. The geometric standard deviation was determined by plotting percentile consumption values taken from Pao et al. (1982).

3.2.3. Fraction of vegetables that are home grown

For the fraction of vegetables that are home grown, the USNRC (1977a) recommends a value of 1.0 for leafy vegetables and 0.76 for other vegetables. The more recent survey conducted by Hamby (1991) determined the same values whereas a survey for SRS around 1980 recommended values of 0.75 and 0.76 for leafy and other vegetables, respectively.

According to the USDA (1955) half of the vegetables are grown at home. South Carolina (and the Savannah River area) has a long growing season lasting about 9 months with some types of leafy vegetables potentially being produced year round. Using the 1955 survey values (0.5) as the likeliest value, a triangular distribution is assigned for both non-leafy and other vegetables. Considering growing seasons, the ranges for non-leafy and leafy vegetables are assumed to be 0.25 to 0.75 and 0.25 to 1.0, respectively.

3.2.4. Fraction of nuclide deposited that remains on the surface of the plant

The fraction of nuclide deposited that remains on the plant surface is primarily a function of type and density of vegetation, particle size, and rainfall rate. Due to the high dependence on rainfall rate, this parameter can vary greatly.

Following nuclear weapons tests, I-131 concentrations were measured in rain and vegetation showing a large range of variation. These experiments yield a uniform distribution with limits of 0.09 to 0.9 (Bouville et al. 1990).

3.2.5. Weathering Rate

In addition to radiological decay, once radionuclides are deposited on vegetation surfaces environmental processes will begin to remove them. The major removal processes are wind removal, water removal, growth dilution, and herbivorous grazing. These removal processes are represented by the weathering rate. This effective removal rate includes the sum of environmental losses and radioactive losses. Given the short radiological half-life of I-131 (8 days), the weathering losses have little effect on total removal.

The default recommended by USNRC (1977a) for environmental losses is 18.07 /yr (14 day effective half time). Miller and Hoffman (1979) refer to a wide range of experiments involving environmental losses of I-131 with ranges of effective half times between 4 and 30 days for I-131. The mean environmental half time was assumed to be 14 days and follow a lognormal distribution as shown in Miller and Hoffman (1979). A geometric standard deviation of 1.4 is estimated from plots showing percentiles within Hoffman and Baes (1979).

3.2.6. Crop Exposure Time

USNRC Regulatory Guide 1.111 (1977b) assumes a crop exposure time of 60 days which corresponds to the average time it takes for a vegetable to grow to an edible state. Hamby (1991) further refined this estimate to a value of 70 days due to the longer growing season in the south. This number will vary based on vegetable type. The crop exposure time is assumed to have a normal distribution with a mean value of 70 and a standard deviation of 7 days.

3.2.7. Productivity for other vegetables

For South Carolina in 1969, there were six principal fresh market vegetables: cabbage, cantaloupes, cucumbers, snap beans, tomatoes, and watermelons. Productivity for these vegetables averaged 0.6 kg/m^2 with a standard deviation of 0.19 (Taylor 1971). Data for Georgia for 1959 was not detailed enough to determine vegetable productivity. Using a wider range of types of vegetables Hamby (1991) determined a productivity of 0.7 kg/m^2 with a lognormal distribution. The 1969 data for South Carolina will be used with a mean of 0.6 kg/m^2 and a geometric standard deviation of 1.4 following a lognormal distribution.

3.2.8. Productivity of leafy vegetables

Data on leafy vegetable production for the period of the late fifties is nonexistent. Currently leafy and other vegetables are assumed to have the same productivity. Therefore, a mean of 0.6 kg/m^2 will be assumed with a geometric standard deviation of 1.4 with the data being lognormally distributed. This agrees with the distribution for other vegetables.

3.2.9. Soil/Plant Uptake Ratio

For iodine, USNRC Regulatory Guide 1.109 recommended a soil/plant uptake ratio of 0.02. This value was taken from studies done in the 1960’s by Ng et al. (1968). Sheppard et al. (1993) performed detailed experiments on soil/plant uptake ratios for several elements including iodine. The crops that were analyzed included beets, cabbage and corn. Values ranged from 0.024 to

0.15 with a weighted average of 0.09 over all vegetation types. Since these values vary according to vegetation type, a uniform distribution is assumed with a range of 0.02 to 0.2.

3.2.10. Time over which buildup of radionuclides occur

Time over which buildup of radionuclides occur refers to that time period which the process has been operating. Operations at SRS began in 1954 so for the time period of 1955-1961 the buildup time would be anywhere from 1 to 7 years. When actual monthly releases are modeled the appropriate number of years could be input, but otherwise a uniform distribution between 1 and 7 years is assumed.

3.2.11. Surface Soil Density

The bulk density of soil at SRS averages 1.6 g/cm^3 with a standard deviation of 0.11 (Looney et al. 1987). This corresponds to a surface soil density of 240 kg/m^2 with a standard deviation of 17. A normal distribution is assumed.

3.2.12. Hold-up time after Harvest

This parameter represents the time after harvest that the produce sits before being consumed by the individual. USNRC Regulatory Guide 1.109 (1977a) recommends values of 1 day and 6 days for leafy vegetables and non-leafy vegetables, respectively (Note: Reg Guide says 60 days, but this is a known typographical error). In lieu of no better data being obtainable, these values are used as the means for this study. A normal distribution is assigned with standard deviations of 0.1 days and .6 days for leafy and other vegetables respectively.

All other parameters not addressed have the same uncertainties as those listed under the previously discussed pathways.

3.3. Milk and Beef Consumption Pathways

Since the consumption of milk and beef use many parameters that overlap, these parameters are addressed together.

3.3.1. Fraction of Time Cattle Spend on Pasture

The fraction of time that cattle spend on pasture was not specifically identified in Regulatory Guide 1.109, but is obtained from the GASPAR manual (Eckerman et al. 1980). The recommended value is 0.75 for both beef and milk cattle. This parameter was further refined by Hamby (1991) for southern climates and increased to 1.0. A uniform distribution is assumed with a range of 0.75 to 1.0 for both beef and milk cattle.

3.3.2. Fraction of time Grazing while on Pasture

The fraction of time that cattle graze while on pasture was not specifically identified in Regulatory Guide 1.109, but is obtained from the GASPAR manual (Eckerman et al. 1980). The recommended value was conservatively assumed to be 1.0 for both beef and milk cattle. Hamby (1991) further refined this parameter to values of 0.56 and 0.75 for milk and beef cows, respectively.

Consumption by cattle varies by age, type, and season. According to Williams (1958) and Allen (1966) cattle thrive on a combination of grazing on coastal bermuda grass, grain, and hay. Coastal bermuda grass grazing begins in the spring and continues typically through the end of the year at which time supplemental feeding includes greater amounts of hay. Therefore, roughly three months out of the year grazing is at a minimum. During the other times of the year grazing is still supplemented with grain and or hay. A uniform distribution is assigned with a range of 0.5 to 0.75 for both beef and milk cattle.

3.3.3. Feed Transfer Coefficients

This parameter represents the ratio of equilibrium between the concentration of I-131 in milk or meat to the daily amount ingested by the animal. According to USNRC Regulatory Guide 1.109 (1977a), the values for meat and milk are 2.9E-03 d/kg and 6.0E-03 d/liter. For milk, Hoffman and Baes (1979) recommend a lognormal distribution with a mean value of 1.2E-02 d/liter. For meat the USRNC Regulatory Guide value of 2.9E-03 d/kg is used as the mean with a lognormal distribution. The geometric standard deviations for transfer factors for meat and milk are estimated to be 2.2 and 2.0 respectively. These geometric standard deviations were estimated from probability plots contained within Hoffman and Baes (1979).

3.3.4. Cattle Feed Rate

According to USNRC Regulatory Guide 1.109 feed consumption rates for both milk and beef cows is assumed to be 50 kg/d (wet weight). This estimate was further refined by Hamby (1991) to be 36 kg/d and 52 kg/d for beef and milk cows, respectively. A normal distribution is assumed for both with a standard deviation of 8 and 11 kg/d for beef and milk cows, respectively.

3.3.5. Crop Exposure Time

Crop exposure time for both pasture grass and stored feed is assumed to have the same distribution as crop exposure time for vegetables: a normal distribution, mean 70 days and standard deviation of 7 days.

3.3.6. Hold up Time

Hold up time would essentially be zero for pasture grass since grazing is continual. However, this would not be the case when rotational grazing is used (Suman and Woods 1966). This practice includes rotating animals every 7-10 days and the grass is fertilized and mowed as necessary. Therefore a custom distribution is assumed with a value of zero 75% of the time and 7 days for the remaining 25% of the time.

For stored feed Hamby (1991) recommends a hold-up time of 90 days. This value is used as the mean of a normal distribution with a standard deviation of 9 days.

3.3.7. Transport Time

Transport time refers to the time period from milking to consumption and slaughter to consumption for milk and beef cows, respectively. According to USNRC Regulatory Guide 1.109 (USNRC 1977a) the transport times for milk and beef are 4 days and 20 days, respectively. Hamby (1991) further refined these estimates by conversations with local farmers to 3 days and 6 days for milk and beef, respectively. No information could be obtained for these times for the late fifties. However, in USDA (1955) the statement is made that 68% of the milk is home-produced which would imply a negligible transport time for this portion of the population. With this in mind, a lognormal distribution is assigned to milk transport time with a mean of 3 days and a geometric standard deviation of 1.5. For beef cattle a lognormal distribution is assigned with a mean of 6 days and a geometric standard deviation of 1.4 as taken from Hamby (1993).

3.3.8. Productivity of pasture grass, Y_v

Productivity data for pasture grass for the late fifties are nonexistent therefore, the USNRC default of 0.7 kg/m^2 (USNRC 1977a) will be used as the mean for a lognormal distribution with a geometric standard deviation of 1.8 as estimated from probability plots within Hoffman and Baes (1979).

3.3.9. Productivity for stored feed

For the late fifties, the primary type of stored feed used for cattle consumption was hay. Georgia county farm statistics (USDA 1967) were consulted for the yield for 1959. For South Carolina, data was found for 1969 (Taylor1971). Plotting this data yielded a lognormal distribution with a mean of 0.4 and a geometric standard deviation of 1.4. The use of a lognormal distribution agrees with later published data by Hoffman and Baes (1979).

3.3.10. Milk Consumption Rate

Milk consumption is typically reported for total milk products consumed including cheese, yogurt, ice cream and etc. The USNRC (1977a) default for milk consumption is 110 L/yr for the average individual and 310 L/yr for the maximally exposed individual. Hamby (1993) recommends a value of 77 L/yr with a lognormal distribution. Using the USDA survey (USDA 1955), which has the limitations discussed under the vegetable consumption section, the single household has an average consumption of 210 L/yr for regions in the South. Also this same study states that only 68% of the milk is produced at home.

More recent studies that discuss the trending of consumption of various commodities say the consumption of milk has decreased over the years specifically with a percentage decrease of 12% from the 1985 to the 1989 surveys. Consumption of fat has greatly decreased in recent years, but this has no effect on milk consumption since there has been a reduction in the consumption of whole milk and an increase in the consumption of skim and reduced fat milks.

Milk consumption is assumed to be 140 L/yr with a lognormal distribution and a geometric standard deviation of 2.6. This mean is equivalent to the average household consumption for the period adjusted by the fraction that is home-produced and is also higher than the current values that are used. The geometric standard deviation was estimated from plots of consumption data taken from Pao et al. (1982).

3.3.11. Beef Consumption Rate

The USNRC (1977a) default for consumption of beef is 95 kg/yr and 110 kg/yr for the average and maximally exposed individual, respectively. Hamby (1991) further refined this estimate to 43 kg/yr for the average individual and 81 kg/yr for the maximally exposed individual.

From the USDA (1955) survey, the average consumption of meat, poultry, and fish was 110 kg/yr for single households. This average includes waste, which is discarded. As stated earlier, diets were higher in fat in the 1950’s when compared to current day (USDA 1955). Beef is one food group from which the higher amounts of fat were obtained.

Beef consumption is assumed to have a mean value of 90 kg/yr and follow a lognormal distribution with a geometric standard deviation of 2.6. The geometric standard deviation was estimated from plots of consumption data taken from Pao et al. (1982).

All other parameters not addressed have the same uncertainties as those listed under the previously discussed pathways.

3.4. Ground Shine Pathway

3.4.1. Shielding Factor

The shielding factor that is recommended by USNRC Regulatory Guide 1.109 is 0.5 (USNRC 1977a). Due to unimportance of this factor a uniform distribution is arbitrarily assigned with a range of 0 to 1.0.

3.5. Uncertainty in Transport Factors

Uncertainty in the transport factors was propagated using the above-defined parameters and the software Crystal Ball ©. Crystal Ball © uses any Microsoft Excel spreadsheet and applies either Latin Hypercube sampling or Monte Carlo simulations to estimate uncertainty from defined equations.

A spreadsheet called MAXINE (Hamby 1994) was utilized with Crystal Ball to propagate the uncertainties. MAXINE generates estimates of maximum individual dose from routine releases of radionuclides to the atmosphere given relative air concentrations and relative depositions as input. To develop a probability distribution solely for the transport factors, dispersion factors and dose conversion factors were set to constant values of one and the release amount was set to 2.7E-11 Ci/yr, which equates to 1 Bq per year. Therefore, the resulting 'doses' actually represent the transport factors for each of the pathways. Figures 1 through 5 show the transport factors for each pathway. The results of this analysis are shown in Appendix A in their entirety. The report includes the frequency distributions for each of the pathways as well as a report showing sensitivity.

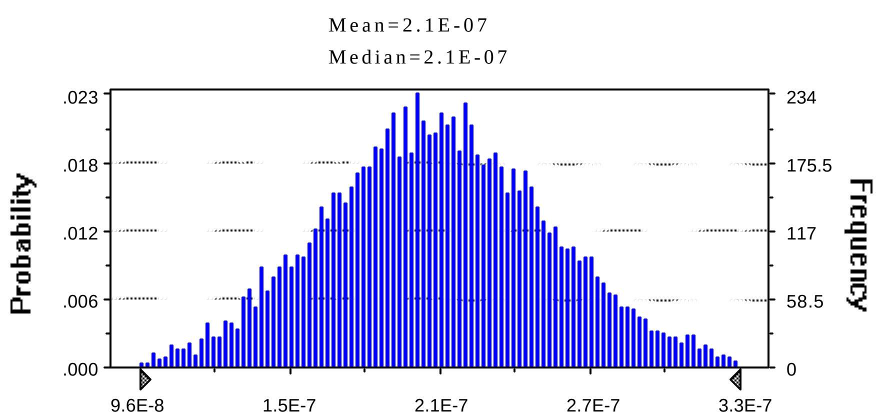


Figure 1. Transport Factor for Inhalation

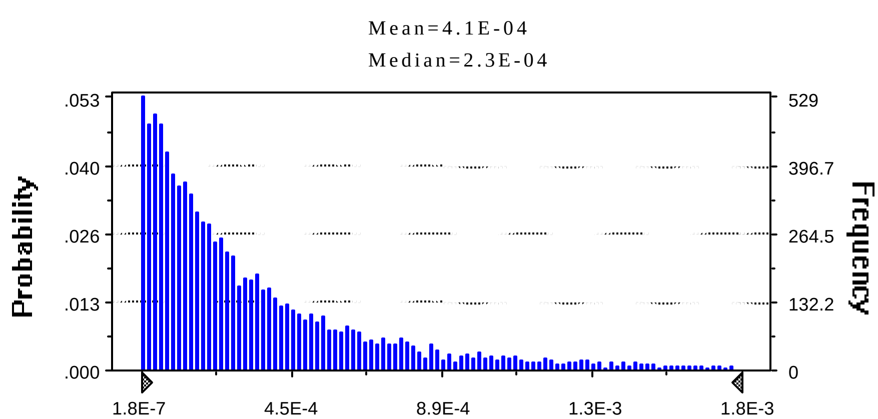


Figure 2. Transport Factor for Ingestion of Vegetables

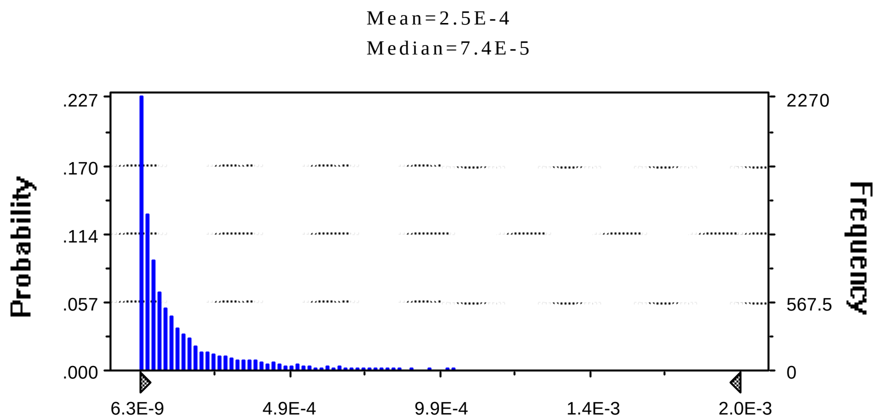


Figure 3. Transport factor for Ingestion of Milk

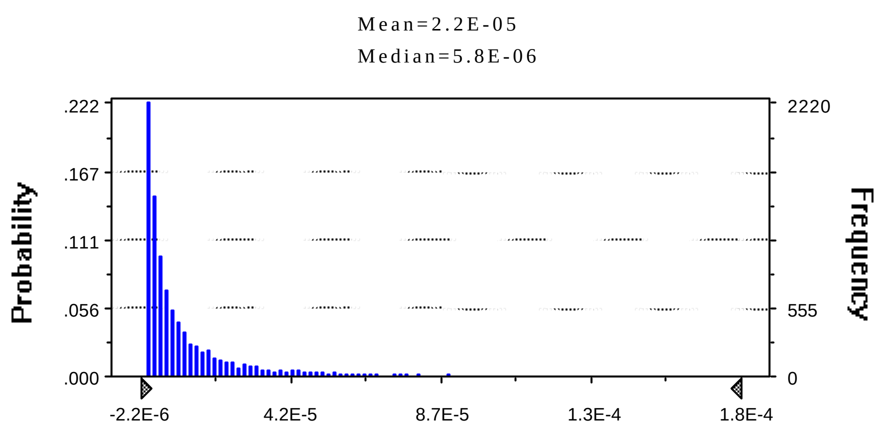


Figure 4. Transport Factor for Ingestion of Beef

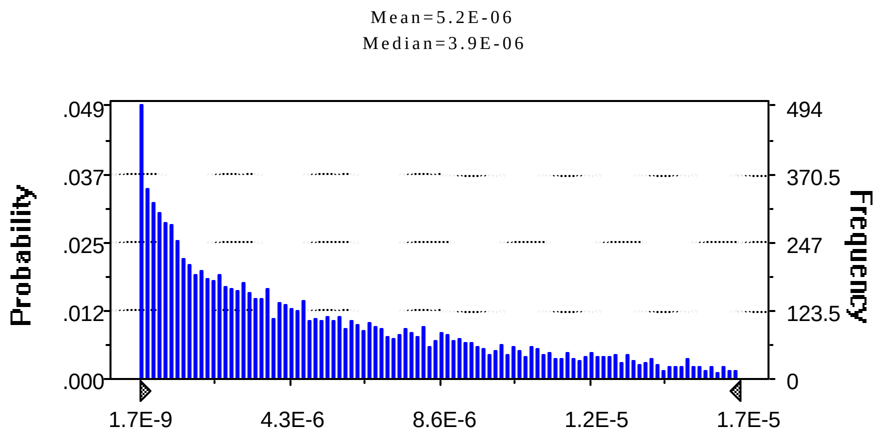


Figure 5. Transport Factor for Shine

4. CONCLUSIONS

Uncertainties have been determined for transport factors used to calculate offsite dose. By performing a preliminary sensitivity analysis, research areas were more focused. This allowed for the uncertainty analysis to be completed in a timely and cost-effective manner. The parameter that appears to have the biggest effect on dose is the fraction of iodine that is elemental. Further research in this area could greatly improve the uncertainty estimates.

5. REFERENCES

Allen, L.R. Coastal Bermudagrass for grazing, hay and silage. United States Deparment of Agriculture and Clemson University: Circular 406, July 1966.

Bouville, A.; Dreicer, M.; Beck, H.L.; Hoecher, W.H.; Wachholz, B.W. Models of Radioiodine Transport to Populations within the Continental U.S. Health Physics Journal, 59(5): 659-668; 1990.

Eckerman, K.F., Congel, F.J., Roecklien, A.K., and Pasciak, W.J. User’s Guide to GASPAR Code. NUREG/-0597, U.S. Nuclear Regulatory Commission, Washington, DC, June 1980.

Hamby, D.M. Land and Water Use Characteristics in the Vicinity of the Savannah River Site. Westinghouse Savannah River Report: WSRC-RP-91-17, March 1991.

Hamby, D.M. A Probabilistic Estimation of Atmospheric Tritium Dose. Health Physics Journal, 65(1): 33-40; 1993.

Hamby, D.M. MAXINE: An improved Methodology for Estimating Maximum Individual Dose from Chronic Atmospheric Radioactive Release. Westinghouse Savannah River Report: WSRC-TR-94-053, Aiken, SC; 1994.

Hoffman, F. O. and Baes III, C.G,. (editors) A Statistical Analysis of Selected Parameters for Predicting Food Chain Transport and Internal Dose of Radionuclides. U.S. Nuclear Regulatory Commission: NUREG/TM-282: 1979.

Kantelo, M.V.; Bauer, L.R.; Marter, W.L.; Murphy, Jr. C.E.; and Zeigler, C.C. Radioiodine in the Savannah River Site Environment. Westinghouse Savannah River Report: WSRC-RP-90-424-2, Aiken, SC; 1990.

Looney, B.B.; Grant, M.W.; and King, C.M. Estimation of Geochemical Parameters for Assessing Subsurface Transport at the Savannah River Plant. Dupont Technical Report: DPST-85-904, Aiken, SC; 1987.

Ng, Y.C. et al. Prediction of the Maximum Dosage to Man from the Fallout of Nuclear Devices, Handbook for Estimating the Maximum Internal Dose from Radionuclides Released to the Biosphere. USAEC Report UCRL-50163, Part IV, 1968.

Pao, E.M.; Fleming, K.H., Guenther, P.M.; and Mickle, S.J. Foods commonly eaten by individuals: Amounts per day and per eating occasion. Washington, DC: Humans Nutrition Information Service; U.S. Department of Agriculture: Report No. 44; 1982.

Sheppard, S.C; Evenden, W.G.; and Amiro, B.D. Investigation of the Soil-to-Plant Pathway for I, Br, Cl, and F. Journal of Environmental Radioactivity, 21: 9-32, 1993.

Simpkins, A.A. MAXDOSE-SR: A Routine Release Atmospheric Dose Model Used at SRS. Westinghouse Savannah River Technical Report: WSRC-TR-99-00281, Aiken, SC; 1999.

Suman, R.F. and Woods, S.G. Beef Production from Coastal Bermudagrass, South Carolina Agricultural Experiment Station Bulletin 524, January 1966.

Taylor, J. S. South Carolina Crop Statistics. United States Department of Agriculture, South Carolina Crop and Livestock Reporting Service, Columbia, SC August, 1971.

Tippet, K.S; Enns, C.W.; and Moshfegh, A.J. Nutrient Update: Food Consumption Surveys in the US Department of Agriculture. Nutrition Today, 34(1); January/February 1999.

U. S. Department of Agriculture. Dietary Levels of Households in the United States. Washington, DC: U.S. Government Printing Office; Report No. 6; 1955.

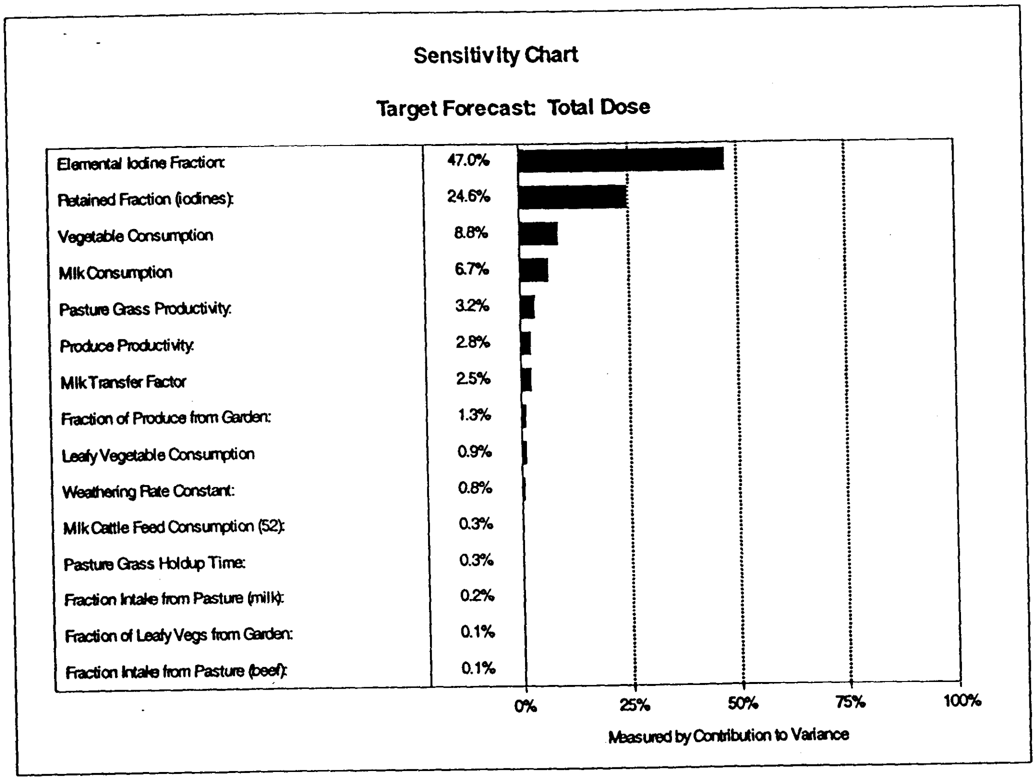
U. S. Department of Agriculture. County Farm Statistics 1900-1966. Athens Georgia: Georgia Crop Reporting Service; 1967.

U. S. Department of Agriculture. Food and Nutrient Intake of Individuals in the United States, Spring 1965. Household Consumption Survey 1965-1966. Washington, DC: U.S. Government Printing Office; Report No. 11; 1965.

Williams, R.O. Beef Cattle Production in Georgia, Bulletin #62: Agricultural Extension Service: University of Georgia College of Agriculture, Athens, Georgia, December 1958.

APPENDIX A. Transport Factor Uncertainty Using Crystal Ball

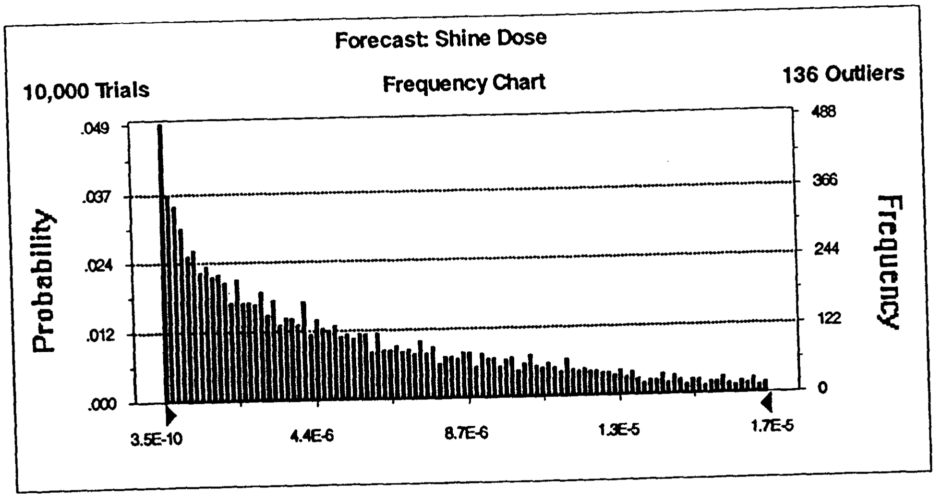
Crystal Ball Report
Simulation started on 11/8/01 at 15:29:01
Simulation stopped on 11/8/01 at 15:31:04



Forecast: Shine Dose **Cell: B270**

Summary:
Display Range is from 3.5E-10 to 1.7E-5
Entire Range is from 3.5E-10 to 2.0E-5
After 10,000 Trials, the Std. Error of the Mean is 4.6E-8

Statistics:	Value
Trials	10000
Mean	5.2E-06
Median	3.9E-06
Mode	---
Standard Deviation	4.6E-06
Variance	2.1E-11
Skewness	0.98
Kurtosis	3.16
Coeff. of Variability	0.88
Range Minimum	3.5E-10
Range Maximum	2.0E-05
Range Width	2.0E-05
Mean Std. Error	4.58E-08



Forecast: Shine Dose (cont'd) **Cell: B270**

Percentiles:

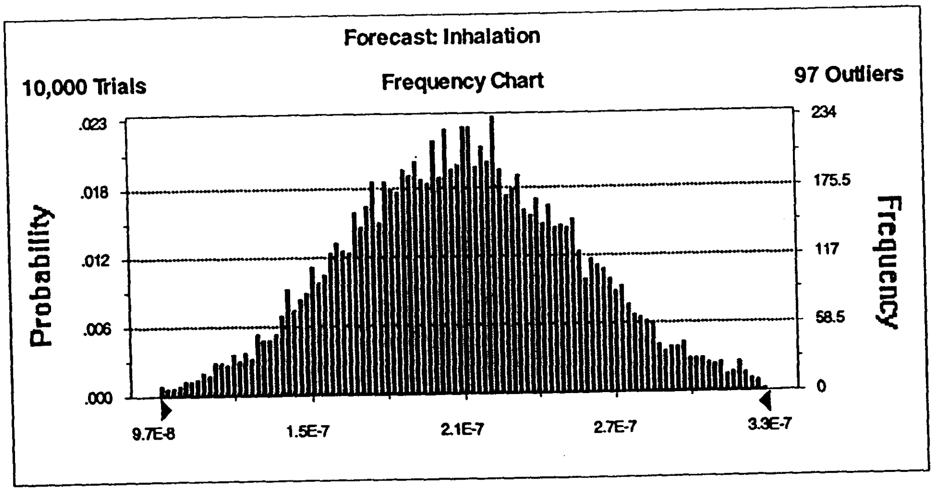
Percentile	Value
0%	3.5E-10
10%	4.2E-07
20%	1.0E-06
30%	1.8E-06
40%	2.8E-06
50%	3.9E-06
60%	5.2E-06
70%	6.9E-06
80%	9.2E-06
90%	1.2E-05
100%	2.0E-05

End of Forecast

Forecast: Inhalation **Cell: C270**

Summary:
Display Range is from 9.7E-8 to 3.3E-7
Entire Range is from 5.3E-8 to 4.0E-7
After 10,000 Trials, the Std. Error of the Mean is 4.5E-10

Statistics:	Value
Trials	10000
Mean	2.1E-07
Median	2.1E-07
Mode	---
Standard Deviation	4.5E-08
Variance	2.0E-15
Skewness	0.08
Kurtosis	2.97
Coeff. of Variability	0.21
Range Minimum	5.3E-08
Range Maximum	4.0E-07
Range Width	3.5E-07
Mean Std. Error	4.46E-10



Forecast: Inhalation (cont'd) **Cell: C270**

Percentiles:

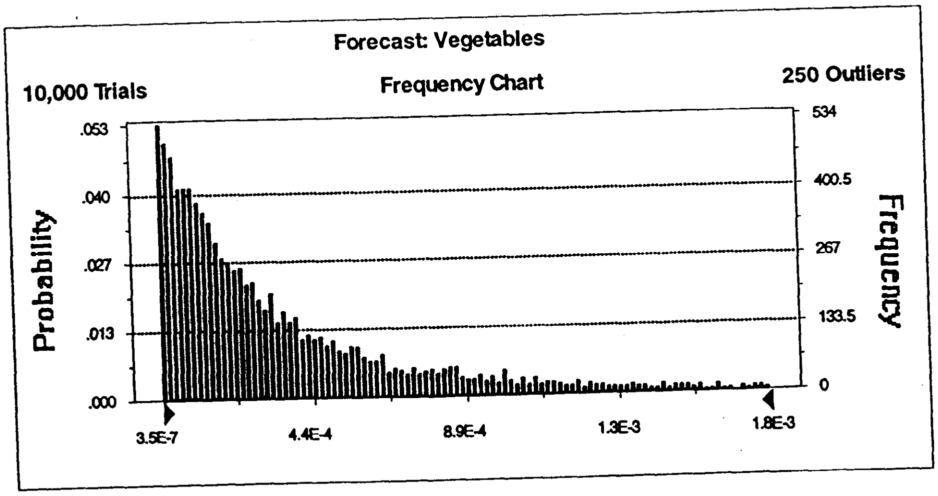
Percentile	Value
0%	5.3E-08
10%	1.6E-07
20%	1.7E-07
30%	1.9E-07
40%	2.0E-07
50%	2.1E-07
60%	2.2E-07
70%	2.3E-07
80%	2.5E-07
90%	2.7E-07
100%	4.0E-07

End of Forecast

Forecast: Vegetables **Cell: D270**

Summary:
Display Range is from 3.5E-7 to 1.8E-3
Entire Range is from 4.0E-8 to 7.3E-3
After 10,000 Trials, the Std. Error of the Mean is 5.1E-6

Statistics:	Value
Trials	10000
Mean	4.0E-04
Median	2.4E-04
Mode	---
Standard Deviation	5.1E-04
Variance	2.6E-07
Skewness	3.68
Kurtosis	26.64
Coeff. of Variability	1.28
Range Minimum	4.0E-08
Range Maximum	7.3E-03
Range Width	7.3E-03
Mean Std. Error	5.13E-06



Forecast: Vegetables (cont'd) **Cell: D270**

Percentiles:

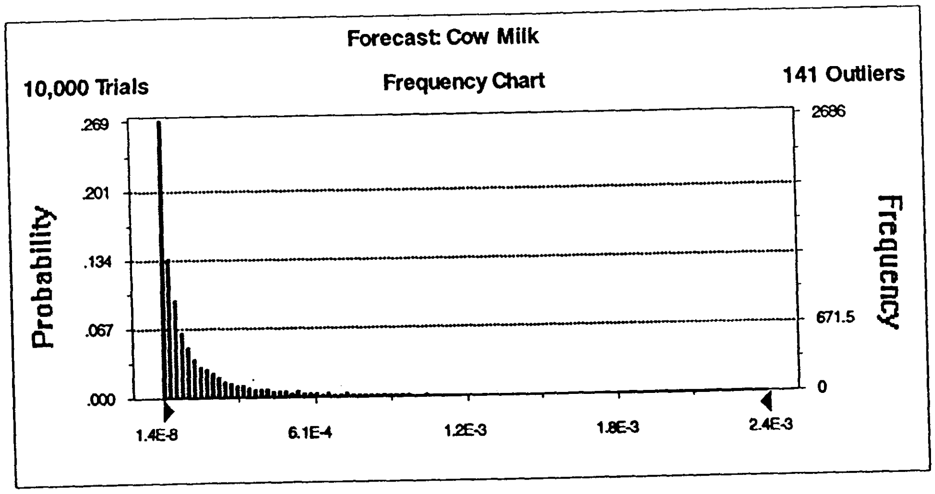
Percentile	Value
0%	4.0E-08
10%	3.5E-05
20%	7.4E-05
30%	1.2E-04
40%	1.7E-04
50%	2.4E-04
60%	3.2E-04
70%	4.3E-04
80%	6.1E-04
90%	9.5E-04
100%	7.3E-03

End of Forecast

Forecast: Cow Milk **Cell: E270**

Summary:
Display Range is from 1.4E-8 to 2.4E-3
Entire Range is from 1.4E-8 to 3.9E-2
After 10,000 Trials, the Std. Error of the Mean is 8.0E-6

Statistics:	Value
Trials	10000
Mean	2.7E-04
Median	7.2E-05
Mode	---
Standard Deviation	8.0E-04
Variance	6.4E-07
Skewness	19.46
Kurtosis	723.52
Coeff. of Variability	2.99
Range Minimum	1.4E-08
Range Maximum	3.9E-02
Range Width	3.9E-02
Mean Std. Error	7.98E-06



Forecast: Cow Milk (cont'd) **Cell: E270**

Percentiles:

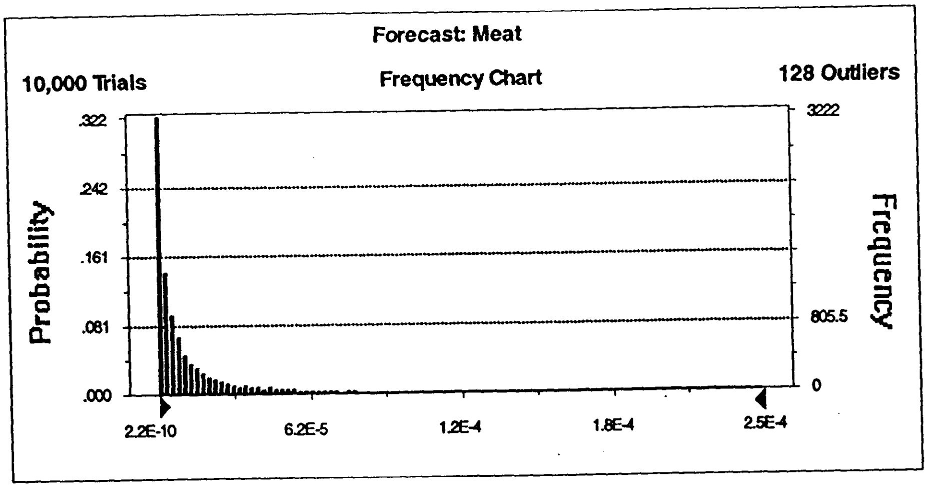
Percentile	Value
0%	1.4E-08
10%	6.6E-06
20%	1.6E-05
30%	2.8E-05
40%	4.7E-05
50%	7.2E-05
60%	1.1E-04
70%	1.8E-04
80%	3.1E-04
90%	6.2E-04
100%	3.9E-02

End of Forecast

Forecast: Meat **Cell: F270**

Summary:
Display Range is from 2.2E-10 to 2.5E-4
Entire Range is from 2.2E-10 to 4.4E-3
After 10,000 Trials, the Std. Error of the Mean is 8.3E-7

Statistics:	Value
Trials	10000
Mean	2.3E-05
Median	5.8E-06
Mode	---
Standard Deviation	8.3E-05
Variance	6.9E-09
Skewness	25.05
Kurtosis	1,063.39
Coeff. of Variability	3.63
Range Minimum	2.2E-10
Range Maximum	4.4E-03
Range Width	4.4E-03
Mean Std. Error	8.32E-07



Cell: **F270**

Forecast: Meat (cont'd)

Percentiles:

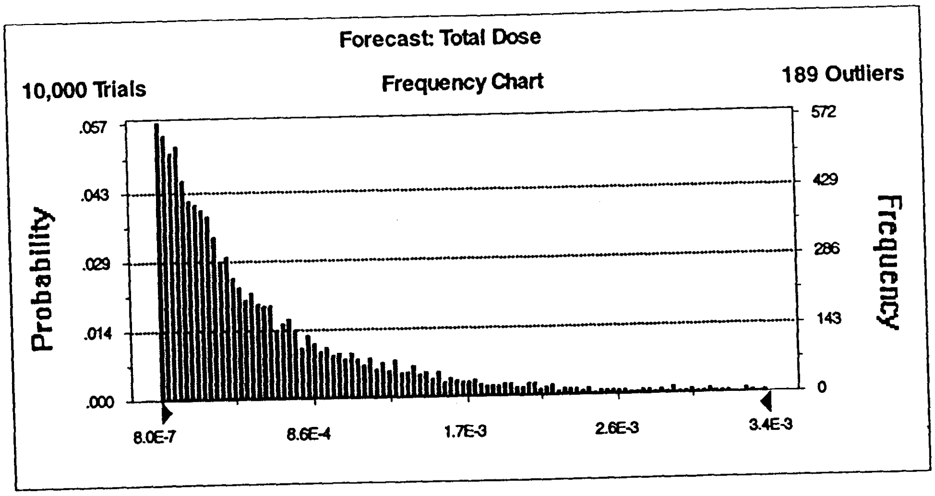
Percentile	Value
0%	2.2E-10
10%	4.9E-07
20%	1.2E-06
30%	2.2E-06
40%	3.6E-06
50%	5.8E-06
60%	8.8E-06
70%	1.4E-05
80%	2.4E-05
90%	5.0E-05
100%	4.4E-03

End of Forecast

Forecast: Total Dose **Cell: G270**

Summary:
Display Range is from 8.0E-7 to 3.4E-3
Entire Range is from 2.1E-7 to 4.0E-2
After 10,000 Trials, the Std. Error of the Mean is 1.0E-5

Statistics:	Value
Trials	10000
Mean	7.0E-04
Median	4.0E-04
Mode	---
Standard Deviation	1.0E-03
Variance	1.1E-06
Skewness	10.43
Kurtosis	275.88
Coeff. of Variability	1.50
Range Minimum	2.1E-07
Range Maximum	4.0E-02
Range Width	4.0E-02
Mean Std. Error	1.04E-05



Forecast: Total Dose (cont'd) **Cell: G270**

Percentiles:

Percentile	Value
0%	2.1E-07
10%	6.2E-05
20%	1.3E-04
30%	2.0E-04
40%	2.9E-04
50%	4.0E-04
60%	5.5E-04
70%	7.4E-04
80%	1.0E-03
90%	1.6E-03
100%	4.0E-02

End of Forecast

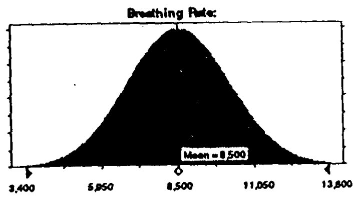
Assumptions

Assumption: Breathing Rate: **Cell: D20**

Normal distribution with parameters:

Mean	8,500
Standard Dev.	1,700

Selected range is from -Infinity to +Infinity

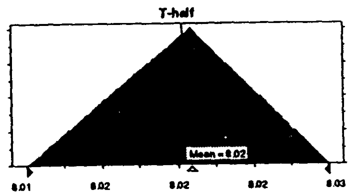


Assumption: T-half **Cell: K172**

Triangular distribution with parameters:

Minimum	8.01
Likeliest	8.02
Maximum	8.03

Selected range is from 8.01 to 8.03

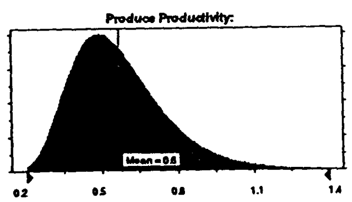


Assumption: Produce Productivity: **Cell: D32**

Lognormal distribution with parameters:

Geometric Mean	0.6
Geometric Std. Dev	1.4

Selected range is from 0.0 to +Infinity

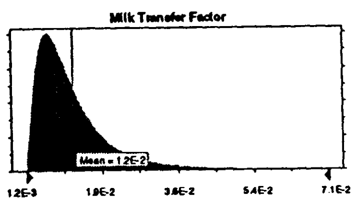


Assumption: Milk Transfer Factor **Cell: F173**

Lognormal distribution with parameters:

Geometric Mean	9.6E-03
Geometric Std. Dev	2.0E+00

Selected range is from 0.0E+0 to +Infinity

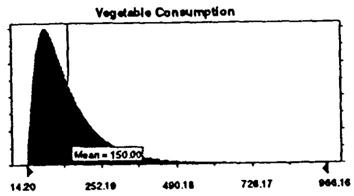


Assumption: Vegetable Consumption **Cell: E14**

Lognormal distribution with parameters:

Geometric Mean	117.13
Geometric Std. Dev	2.02

Selected range is from 0.00 to +Infinity

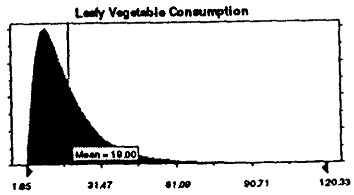


Assumption: Leafy Vegetable Consumption **Cell: E15**

Lognormal distribution with parameters:

Geometric Mean	14.91
Geometric Std. Dev	2.01

Selected range is from 0.00 to +Infinity

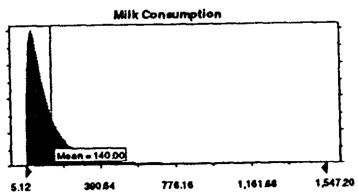


Assumption: Milk Consumption **Cell: E16**

Lognormal distribution with parameters:

Geometric Mean	89.00
Geometric Std. Dev	2.59

Selected range is from 0.00 to +Infinity

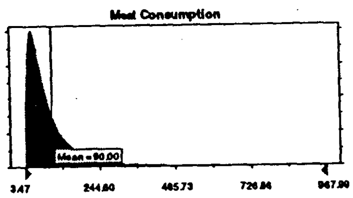


Assumption: Meat Consumption **Cell: E17**

Lognormal distribution with parameters:

Geometric Mean	57.93
Geometric Std. Dev	2.56

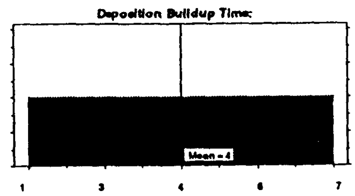
Selected range is from 0.00 to +Infinity



Assumption: Deposition Buildup Time: **Cell: D19**

Uniform distribution with parameters:

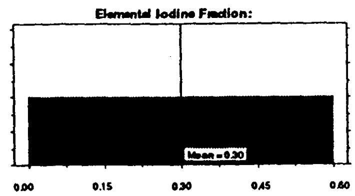
Minimum	1
Maximum	7



Assumption: Elemental Iodine Fraction: **Cell: D21**

Uniform distribution with parameters:

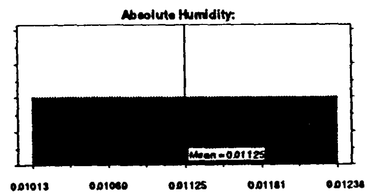
Minimum	0.00
Maximum	0.60



Assumption: Absolute Humidity: **Cell: D22**

Uniform distribution with parameters:

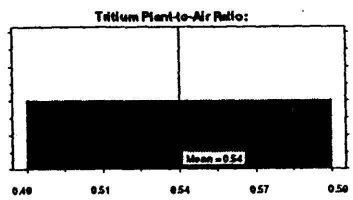
Minimum	0.01013
Maximum	0.01238



Assumption: Tritium Plant-to-Air Ratio: **Cell: D23**

Uniform distribution with parameters:

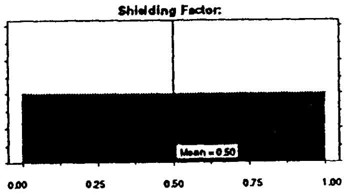
Minimum	0.49
Maximum	0.59



Assumption: Shielding Factor: **Cell: D24**

Uniform distribution with parameters:

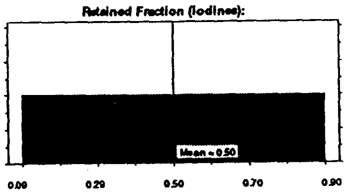
Minimum	0.00
Maximum	1.00



Assumption: Retained Fraction (iodines): **Cell: D26**

Uniform distribution with parameters:

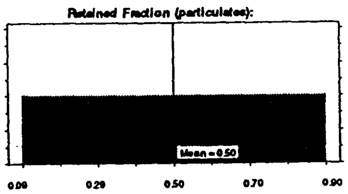
Minimum	0.09
Maximum	0.90



Assumption: Retained Fraction (particulates): **Cell: D27**

Uniform distribution with parameters:

Minimum	0.09
Maximum	0.90

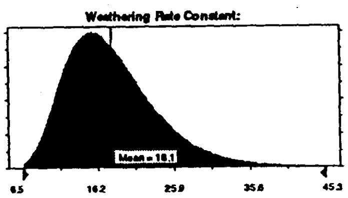


Assumption: Weathering Rate Constant: **Cell: D28**

Lognormal distribution with parameters:

Geometric Mean	17.2
Geometric Std. Dev	1.4

Selected range is from 0.0 to +Infinity

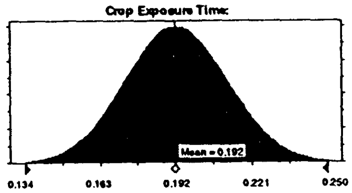


Assumption: Crop Exposure Time: **Cell: D29**

Normal distribution with parameters:

Mean	0.192
Standard Dev.	0.019

Selected range is from -Infinity to +Infinity

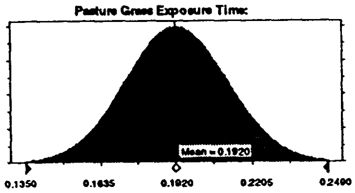


Assumption: Pasture Grass Exposure Time: **Cell: D30**

Normal distribution with parameters:

Mean	0.1920
Standard Dev.	0.0190

Selected range is from -Infinity to +Infinity

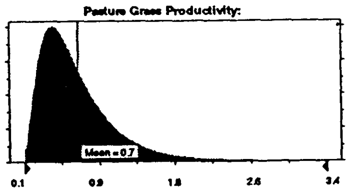


Assumption: Pasture Grass Productivity: **Cell: D31**

Lognormal distribution with parameters:

Geometric Mean	0.6
Geometric Std. Dev	1.8

Selected range is from 0.0 to +Infinity

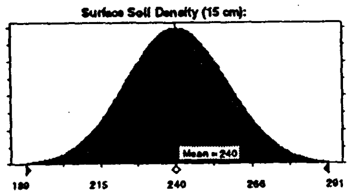


Assumption: Surface Soil Density (15 cm): **Cell: D33**

Normal distribution with parameters:

Mean	240
Standard Dev.	17

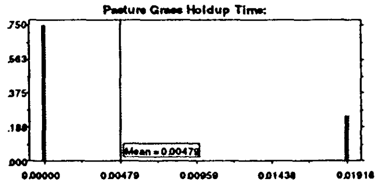
Selected range is from -Infinity to +Infinity



Assumption: Pasture Grass Holdup Time: **Cell: D34**

Custom distribution with parameters:

		Relative Prob.
Single point	0.00000	0.750000
Single point	0.01918	0.250000
Total Relative Probability		1.000000

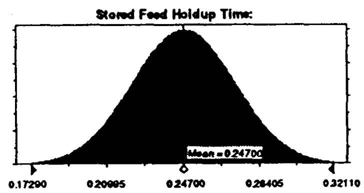


Assumption: Stored Feed Holdup Time: **Cell: D35**

Normal distribution with parameters:

Mean	0.24700
Standard Dev.	0.02470

Selected range is from -Infinity to +Infinity

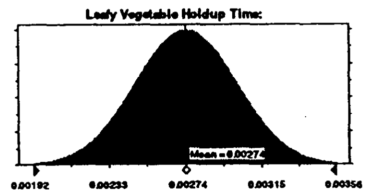


Assumption: Leafy Vegetable Holdup Time: **Cell: D36**

Normal distribution with parameters:

Mean	0.00274
Standard Dev.	0.00027

Selected range is from -Infinity to +Infinity

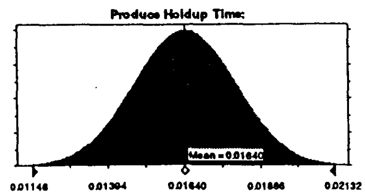


Assumption: Produce Holdup Time: **Cell: D37**

Normal distribution with parameters:

Mean	0.01640
Standard Dev.	0.00164

Selected range is from -Infinity to +Infinity

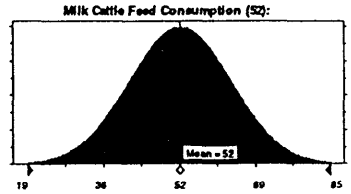


Assumption: Milk Cattle Feed Consumption (52): **Cell: D38**

Normal distribution with parameters:

Mean	52
Standard Dev.	11

Selected range is from -Infinity to +Infinity

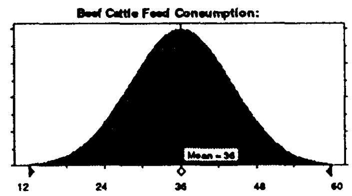


Assumption: Beef Cattle Feed Consumption: **Cell: D39**

Normal distribution with parameters:

Mean	36
Standard Dev.	8

Selected range is from -Infinity to +Infinity

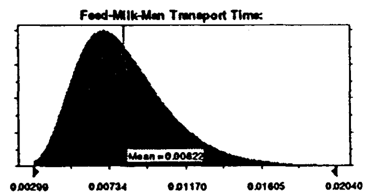


Assumption: Feed-Milk-Man Transport Time: **Cell: D40**

Lognormal distribution with parameters:

Geometric Mean	0.00781
Geometric Std. Dev	1.37725

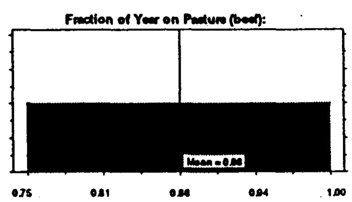
Selected range is from 0.00000 to +Infinity



Assumption: Fraction of Year on Pasture (beef): **Cell: D41**

Uniform distribution with parameters:

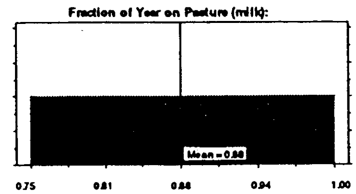
Minimum	0.75
Maximum	1.00



Assumption: Fraction of Year on Pasture (milk): **Cell: D42**

Uniform distribution with parameters:

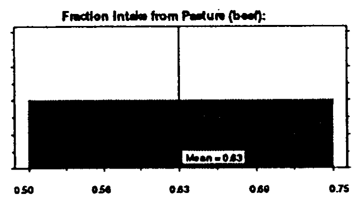
Minimum	0.75
Maximum	1.00



Assumption: Fraction Intake from Pasture (beef): **Cell: D43**

Uniform distribution with parameters:

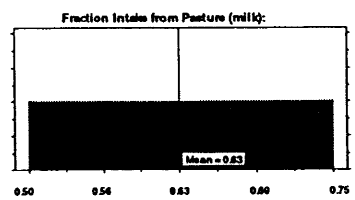
Minimum	0.50
Maximum	0.75



Assumption: Fraction Intake from Pasture (milk): **Cell: D44**

Uniform distribution with parameters:

Minimum	0.50
Maximum	0.75

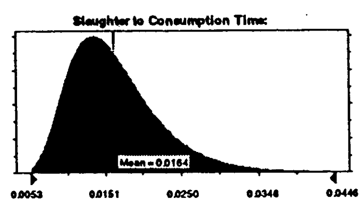


Assumption: Slaughter to Consumption Time: **Cell: D45**

Lognormal distribution with parameters:

Geometric Mean	0.0154
Geometric Std. Dev	1.4254

Selected range is from 0.0000 to +Infinity

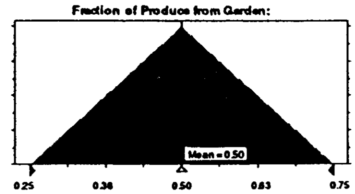


Assumption: Fraction of Produce from Garden: **Cell: D46**

Triangular distribution with parameters:

Minimum	0.25
Likeliest	0.50
Maximum	0.75

Selected range is from 0.25 to 0.75

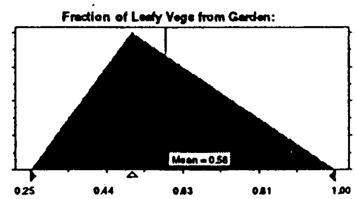


Assumption: Fraction of Leafy Vegs from Garden: **Cell: D47**

Triangular distribution with parameters:

Minimum	0.25
Likeliest	0.50
Maximum	1.00

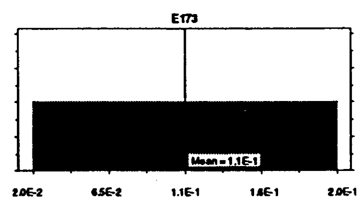
Selected range is from 0.25 to 1.00



Assumption: E173 **Cell: E173**

Uniform distribution with parameters:

Minimum	2.0E-02
Maximum	2.0E-01

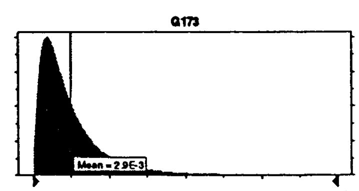


Assumption: G173 **Cell: G173**

Lognormal distribution with parameters:

Geometric Mean	2.2E-03
Geometric Std. Dev	2.2E+00

Selected range is from 0.0E+0 to +Infinity

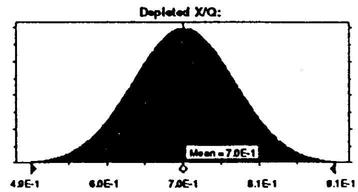


Assumption: Depleted X/Q: **Cell: D11**

Normal distribution with parameters:

Mean	7.0E-01
Standard Dev.	7.0E-02

Selected range is from -Infinity to +Infinity



End of Assumptions